Title	GENETICS OF RACING PERFORMANCE IN THE THOROUGHBRED HORSE OF JAPAN(Dissertation_全文)
Author(s)	Oki, Hironori
Citation	Kyoto University (京都大学)
Issue Date	1994-09-24
URL	http://dx.doi.org/10.11501/3079268
Right	
Type	Thesis or Dissertation
Textversion	author

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HIRONORI OKI

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1994

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INTRODUCTION

The breeding of the Thoroughbred horse started about 300 years ago in England, and about 250 year ago in Europe and North American. In the beginning, many Oriental horses which are Arabian, Turk and Barb horse were imported and bred to the domestic horses in England. In these many Oriental horses which made the Thoroughbred horse, we can now trace back to the three sire; Byerly Turk, Godolphin Arabian and Darley Arabian.

Since the establishment of the General Stud Book (Volume 1) at 1791, this format have been used in almost stud books of each nations. By this reason, the horse traced back to horses which recorded in the General Stud Book define to be the Thoroughbred horse.

The Thoroughbred horses are offsprings of horses of which the their racing performance have been tested on race courses for about 300 years. The official racing record (Volume 1) of the Thoroughbred horse was published in 1751 at first. They have continue to be published by a official association in each nations. Recently, the Thoroughbred should be registered in the official association in each nations.

The body shape and the racing speed of the thoroughbred had been improved rapidly until this century, because they have been selected by racing. However, the racing time of classic races have not improve in recent decades (Gaffney and Cunningham, 1988).

The racing performance of Thoroughbred horse is evaluated usually in this field based on racing time, earnings, earning index, handicap weights, margins of arrivals, placings, performance rates (Gillespie, 1971) and TIMEFORM handicap ratings (these values are compiled, revised periodically, and published by the Timeform organization). In foreign countries, there are some reports by using these indicators (Artz, 1961; Bormann, 1964; Dusek, 1965; Watanabe, 1969, 1974; Schwark and Neisser, 1971; Foye, 1972; More O'Ferrall and Cunningham, 1974; Field and Cunningham, 1976; Gaffney and Cunningham, 1988).

In Japan, the history of breeding for Thoroughbred horses is short. In 1941, the number of horse born in a year totaled only 473, but began to increase from the latter half of the 1960s and in 1987, reached 7,662 (Japan Bloodhorse Breeders Association, 1992). This number is the two-third of the number of horses in Japan. This indicates that the Japanese horse breeding is mainly the racing horse. However, Thoroughbred horses in Japan were believed to be beneath foreign horses in the racing performance. And also, the animal breeding for the horse is later than it of a beef cattle or a milking cow. By this reason, Scientific horse breeding based on race records has not been established yet.

This paper reports the racing time as an indicator of racing performance and establish guides base on them to apply the best linear unbiased prediction (BLUP) method for the Thoroughbred horse in Japan.

CHAPTER 1. DESCRIPTION OF THE DATA

Introduction

The Equine Research Institute of the Japan Racing Association has initiated a research project to study the genetics of racing performance in the Japanese Thoroughbred horse. The ultimate purpose of this project is to provide genetic predictions and performance predictions on all Thoroughbred horses that participate in flat racing on both turf and dirt at the 10 national racecourses operated by the Japan Racing Association. This paper is the first in a series and provides a detailed description of the data. Horse racing in Japan is big business and is highly organized. Results from the studies on the genetics of racing performance will be of interest to the worldwide horse racing community.

Materials and Methods

Japan Racing Association (JRA) was established in 1954 as a publically operated enterprise to provide for the development of wholesome horse racing and to provide for the improvement in the breeding of race horses and other livestock. Half of any surplus profit goes to the National Treasury where by law three-fourth of which is to be designated for livestock improvement.

JRA is operated under the oversight of the Ministry of Agriculture, Forestry, and Fisheries. It is functionally managed by a President, Executive Vice-President, a Board of Directors, a Management Advisory Council, and since 1991 a Horseracing Administration and Adjudication Council. The Horseracing Law as amended provides for national and regional public racing and was revised in 1954 to enact the Japan Racing Association Law. JRA operates under the Japan Racing Association law. Table 1-1 provides a comparison between

Table 1-1. The 1990 comparison of national racing and regional public racing

Item	National racing[a]	Regional public racing[b]
Meeting days	288	2,420
Races	3,353	24,784
Attendance	10,687,344	13,873,716

[a] National racing is operated by JRA at 10 racecourses; sells pari-mutuels; registers owners, horses, and racing colors; licenses trainers and jockeys; and trains jockeys and yearlings.

[b] Regional public racing is operated by local governments. Owners can be registered in both, but trainers and jockeys can not be simultaneously licensed for both. Restrictions exist on interchange of race horses.

national and regional racing. The national racing is controlled and operated by JRA while the regional racing is operated by local governments and is administratively organized by the National Association of Racing. The racing times used in these studies come exclusively from national racing.

JRA manages ten racecourses. See Table 1-2. Since 1975, JRA has continuously operated horse racing a maximum of 288 days each year as prescribed by law. JRA is responsible for wagering, but this aspect of JRA is not discussed here. JRA formulates the rules for horse racing; registers owners, their colors, and race horses using Foal Registrations Certificates; and licenses all JRA trainers and jockeys and has approval authority for hiring of stable employees. Table 1-2 shows that in 1990 at the ten national racecourses there were 288 racing days, 3,353 races, and 38,397 horses. Since some horses race at several race courses, this number is larger than the actual number of horses raced per year. The racing season in Japan is continuous as seen in Table 1-2. Race days are limited to weekends (Saturday and Sunday) and holidays. This schedule is thought to give horses spaced stress and allow for longer careers on the track.

JRA has three types of horse racing. These are Thoroughbred flat races (91.6%), Thoroughbred jumping race (steeplechase) (4.3%), and Anglo-Arab flat races (4.1%). Only the first type is considered in this study. Both Thoroughbred horses and Thoroughbred grade horses can run in Thoroughbred flat races. There are Purse/Plate races where the prize money consists of added money and Stakes Races where the prize money consists of stakes money and added money. Graded races are selected as GI,GII, and GIII. Most graded races are run on turf. All national racecourses have both turf and dirt tracks except the Sapporo racecourse which had only a dirt track until 1989. The

Table 1-2. The racing days, races run by racing month, and the number of horses run at the ten racecourses of JRA in 1990

Racecourse	Racing	Races run on racing month												Horse
	days	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Numbers[a]
Sapporo	16					70	102							1,726
Hakodate	16							84	73					1,551
Fukushima	32				46	45	59	36		19	95	72		4,174
Niigata	16							72	93	22				1,898
Tokyo	40	24	70		48	91	48				91	94		5,002
Nakayama	40	96	24	108	59					96			93	5,525
Chukyo	32			92			60	36		96		24	71	4,732
Kyoto	40	96			47	48					96	93	95	5,908
Hanshin	32	24	95	108	59	48	47							4,540
Kokura	24	24	72					72	96	24				3,341
Total	288	264	261	308	259	232	284	318	273	330	282	283	259	38,397

[a] Since horses race at more than one track, these numbers are larger than the real number of horses racing in 1990. See Table 3

race types (Purse/Plate, Stakes, and Graded) are not considered in the study, but turf and dirt tracks are.

Two year olds race together exclusively and the range of distance is from 1000m to 2000m. Nearly 40% of their races are run at 1200m. Races for 3 year olds is from 1000m to 3000m and some 39% of their races are at 1800m. For 3 (and 4) year olds and up, the range of distance is from 1000m to 3600m on turf and is from 1000m to 2400m on dirt. Some 26% are at 1800m.

Horse breeding in Japan is concentrated in seven localities that stretch the length of Japan. Nearly 93% of Thoroughbred foaled each year are in Hokkaido where nearly 89% of the stock is confined to an area around Hidaka. Stallions are also imported. Bloodstock Sales are conducted by the Japan Blood Horse Breeders Association in cooperation with local breeder's associations. Foals are registered by the Japan Race Horse Registry. Numbers of Thoroughbreds foaled have increased from 283 in 1950, 1,020 in 1960, 4,129 in 1970, 7,447 in 1980, to 9,225 in 1990.

For the analysis of racing time, the records of horses that did not have a racing time because of a racing accident or were off at the finish line for a definite reason, i.e. nasal bleeding, atrial fibrillation and etc., were excluded. Analysis of data was done using the procedure of PC-SAS(1990).

Results and Discussion

Table 1-3 gives the number of races run, the number of horse raced, sire numbers, race records per horse, horses raced per sire, race records per race run, and total race records broken down by horse age and years of racing from 1980 to 1990 in Thoroughbred horse. Also included are the total horses raced and the total number of race records per year. The number of races run averaged over years is 408 for 2 year olds and 2,501 for 3 year olds and up. The number of horse raced averaged

Table 1-3. Races run, horse numbers, sire numbers, race records per horse, horses raced per sire, race records per race run, and total race records in flat races for years and age in Thoroughbred horse

Item	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
2 year olds											
Races run	424	434	439	418	400	397	392	391	389	399	401
Horse numbers	1,132	1,181	1,187	1,110	1,166	1,096	1,137	1,147	1,192	1,230	1,236
Sire numbers	263	264	249	259	263	246	232	242	262	258	271
Records/Horse	4.0	3.7	3.8	3.5	3.5	3.4	3.3	3.3	3.2	3.2	3.3
Horses/Sire	4.3	4.5	4.8	4.2	4.4	4.5	4.9	4.7	4.5	4.8	4.6
Records/Race	10.6	10.1	10.2	9.3	10.3	9.5	9.8	9.8	10.0	10.0	10.2
Race records	4,479	4,376	4,482	3,901	4,118	3,774	3,798	3,808	3,856	3,939	4,050
3 year olds and up											
Races run	2,300	2,345	2,381	2,419	2,493	2,540	2,570	2,590	2,608	2,620	2,648
Horse numbers	3,400	3,510	3,772	3,974	4,415	4,308	4,494	4,511	4,665	4,875	4,991
Sire numbers	385	394	387	402	403	403	403	387	402	413	473
Records/Horse	7.3	7.1	7.1	6.8	6.7	6.6	6.4	6.5	6.5	6.3	6.3
Horses/Sire	8.8	8.9	9.7	9.9	10.3	10.7	11.2	11.7	11.6	11.8	10.6
Records/Race	10.8	10.7	11.3	11.2	11.1	11.2	11.4	11.5	11.7	11.8	11.9
Race records	24,945	24,996	26,847	27,130	27,569	28,553	28,808	29,410	30,129	30,631	31,247
Horses raced	4,532	4,691	4,959	5,074	5,311	5,404	5,531	5,658	5,921	6,170	6,227
Total race records	29,424	29,372	31,329	31,031	31,687	32,327	32,606	33,218	33,985	34,570	35,297

over years is 1,164 for 2 year olds and 4,240 for 3 year olds and up. Race records per horse average 3.5 for 2 year olds and 6.7 for 3 year olds and over. The race records per horse were nearly double for older horses. Sire numbers averaged over year are 255 for 2 year olds and 405 for 3 year olds and over. Horses raced per sire over years average 4.6 for 2 year olds and 10.5 for 3 year olds and over. This distribution will become useful in the estimation of heritability for racing performance. The number of race records per race run averaged over years is 10.0 for 2 year olds and 11.3 for 3 year olds and older. There are more horses per race in the older group. The yearly number of horses raced averaged over years is 5,407 and the total race records averaged over year is 32,259. These data available from JRA constitute a unique set in that there is a high degree of control over factors that can influence racing time in Thoroughbreds.

Tables 1-4 and 1-5 provide information on the number of observations at given distances listed by horse age for 1990 on turf in Table 1-4 and on dirt in Table 1-5 for Thoroughbred horse. Also, the average time in seconds is given for the distances and age of horse. Racing time is less on turf than on dirt. There are more races on turf than dirt for all distances. Older horses run for longer distances than do the two and three year olds.

To examine distance run in 1990, the average seconds was regressed on distance in meters for each horse age on both turf and dirt. Both weighted and unweighted linear and quadratic regressions were fit. Weighting by numbers was used, but the difference was small. None of the quadratic regressions approached significance even at the .05 level, so only linear regressions are reported. The linear regressions were all significant at the .0001 level and all R^2 values were greater than .99. On turf, the linear regressions per 100

Table 1-4. The number of observations at the several distances listed by horse age and the average time at these distances for turf tracks in 1990 for Thoroughbred horse

	2 year olds		3 year olds		4 year and older	
Distance	N	Average time[a]	N	Average time	N	Average time
1,000m	493	60.4 ± .08	338	59.4 ± .06	147	59.3 ± .09
1,200m	1,072	72.3 ± .05	1,835	72.3 ± .04	1,148	71.2 ± .04
1,400m	337	85.5 ± .08	741	85.2 ± .07	411	84.0 ± .08
1,500m			19	91.1 ± .22	23	90.5 ± .20
1,600m	563	98.0 ± .07	1,412	98.2 ± .05	887	96.5 ± .06
1,700m	100	106.4 ± .16	259	105.3 ± .10	93	104.4 ± .15
1,800m	215	112.3 ± .12	2,155	111.8 ± .04	1,533	110.8 ± .05
2,000m	141	125.6 ± .15	2,031	125.0 ± .05	1,772	123.7 ± .06
2,200m			268	138.7 ± .19	250	137.2 ± .16
2,300m			12	141.6 ± .45	57	143.0 ± .41
2,400m			209	149.9 ± .24	215	148.5 ± .14
2,500m			53	156.6 ± .24	352	156.8 ± .13
2,600m			16	163.6 ± .35	96	164.8 ± .21
3,000m			21	188.3 ± .48	20	190.3 ± .66
3,200m					35	202.6 ± .35
3,600m					14	226.5 ± .15
Total	2,921		9,370		7,053	

[a] Mean ± standard error

Table 1-5. The number of observations at the several distances listed by horse age and the average time at these distances for dirt tracks in 1990 for Thoroughbred horse

	2 year olds		3 year olds		4 year and older	
Distance	N	Average time[a]	N	Average time	N	Average time
1,000m	212	62.8 ± .09	1,287	62.0 ± .04	570	61.2 ± .06
1,200m	490	75.2 ± .06	2,111	75.0 ± .03	1,003	73.6 ± .04
1,400m	296	88.5 ± .09	633	87.8 ± .07	562	86.4 ± .06
1,600m	36	101.7 ± .18	374	101.0 ± .11	425	99.2 ± .07
1,700m	16	111.3 ± .45	2,498	110.2 ± .05	1,466	108.9 ± .06
1,800m	48	116.9 ± .30	1,848	116.9 ± .05	1,738	114.7 ± .04
2,100m			3	132.2 ± .50	50	134.4 ± .30
2,300m			20	153.2 ±1.00	39	151.1 ± .45
2,400m					9	156.8 ± .74
	1,098		8,774		5,862	

[a] Mean ± standard error

meters were 6.5s for 2 year olds, 6.6s for 3 year olds, and 6.4s for 4 year and older horses. On dirt, the regressions were 6.7s, 6.9s and 6.8s for the three ages. Again horses were faster on turf than dirt (6.5s vs 6.8s) even though longer distances were raced on turf compared with dirt. As distance increases there appears to be little increase in seconds per 100m as indicated by the minute quadratic regressions. These results suggested that stamina may not be an important factor in racing times. Further these results suggest that the genetic predictions may be accomplished by adjusting for distance run and reporting the predictions in second per 100m.

Table 1-6 reports the number of Thoroughbred foals registered and the number of individual horse registered to JRA and number of horses raced at different ages by sex from 1986 through 1990. Only .2% of the horse race in JRA are geldings. Table 1-6 shows that only 43% of the mares and 42% of the stallions were raced as 2 year olds. But 93% of the mares and stallions were raced as 3 year olds. The 4 year olds represent only 41% of the mares and 51% of the stallions. This decrease represents both the selection of horses to continue racing and the selection of breeding stock, since breeding stock is no longer raced.

The racecourses at Tokyo, Nakayama, Kyoto, and Hanshin stable horses at two training centers, Miho and Ritto. Horses are transported to the tracks. At Sapporo, Hakodate, Fukushima, Niigata, Chukyo, and Kokura, most horses are stabled at the racecourses. Therefore, many horse raced at more than one racecourses in a season. Table 1-7 shows that 73% of the horses raced in 1990 raced at two or more racecourses. This distribution helps tie the racing data together.

Table 1-7 also shows that 90% of the jockeys rode at two or more racecourses in 1990. And 53% rode at either 4 or 5

Table 1-6. Number of Japanese Thoroughbred foals registered in 1984 and individual horses registered to JRA and raced from 1986 thorough 1990

Sex	Foals registered in 1984	Horses registered to JRA	Number of horses raced of horses registered to JRA				
			2 yr 1986	3 yr 1987	4 yr 1988	5 yr 1989	6 yr 1990
Females	3,518	1,209	515	1,121	492	203	67
Males[a]	3,446	1,447	613	1,343	735	378	165

[a] Fewer than .2% of horses raced are geldings

Table 1-7. Distribution of jockeys and horses racing at difference tracks operated by JRA in 1990

Number of raced racecourse	Frequency of Jockeys	Frequency of horses
1	22 (9.6)[a]	1,712 (27.3)
2	13 (5.7)	1,722 (27.5)
3	9 (3.9)	1,475 (23.5)
4	57 (25.0)	1,025 (16.3)
5	63 (27.6)	291 (4.6)
6	44 (19.3)	39 (.6)
7	14 (6.1)	8 (.1)
8	5 (2.2)	
9	1 (.4)	
Total	228 (100.0)	6,272 (100.0)

[a] Percentage in ( )

tracks, so jockeys are distributed across racecourses. Only 6% of the jockeys ride for one trainers as shown in Table 1-8. Thus, the majority of jockeys ride for many different trainers. The JRA horseracing school educates and trains all prospective JRA jockeys and trains stable employees. The JRA trainers and jockeys are licensed.

Ninety percent of registered JRA owners are individual owners. The remainder of owners are companies. Trainers prepare horses for racing for several owners.

The Equine Research Institute of JRA conducts research and development on all facts of the horse racing industry. There are hospitals and clinics at the training centers.

Table 1-8. Distribution of jockeys related with trainers for races in 1990

Number of related trainers	Frequency of jockeys	
1	13	(5.5)[a]
2 - 5	42	(17.8)
6 - 10	38	(16.1)
11 - 15	37	(15.7)
16 - 20	24	(10.2)
21 - 25	12	(5.1)
26 - 30	20	(8.5)
31 - 35	10	(4.2)
36 - 40	14	(5.9)
41 - 85	26	(11.0)
Total	236	(100.0)

[a] Percentage in ( )

CHAPTER 2. ENVIRONMENTAL VARIATION OF RACING TIME ON TURF AND DIRT TRACKS

Introduction

Individual racing records at the ten main race courses in Japan have been maintained by the Japan Racing Association. Racing time is a suitable quantitative measure that can be used to evaluate genetic racing performance of the Thoroughbred horse. The various environmental factors influencing the racing time of horses have been reported by many researchers (Watanabe, 1969; Rönningen, 1975; Hintz and Van Vleck, 1978; Hintz, 1980; Tolley et al., 1983; Ojala et al., 1987; Buttram et al., 1988). The importance of various sources of variation on the total variation of racing time in Japanese Thoroughbred is not known. This was examined using a nested model and analyzing the variation accounted for by the factors, as Buttram et al. (1988) did with American Quarter Horses data.

The purpose of this study was to identify important sources of variation in racing times on both turf and dirt for Thoroughbred horses in Japan. This was done using a nested model and expressing the components of variance as percentages of the total variation. The percentages were compared across turf and dirt tracks.

Materials and Methods

Individual animal racing times of Thoroughbred horses for flat races at the Hakodate, Fukushima, Niigata, Tokyo, Nakayama, Chukyo, Kyoto, and Hanshin racecourses, which have both turf and dirt tracks, from 1982 to 1990 were obtained from the Japan Racing Association (JRA). The data were composed of five racing distances on both turf and dirt track, i.e., 1000m, 1200m, 1400m, 1600m, and 1800m. The ages of the horses were 2, 3, 4 and 5 years. In most cases, more than two records were obtained from an individual horse. The records of horses that were off at the finish line for a definite reason, i.e. nasal bleeding, atrial fibrillation and etc., were excluded. Finish time was measured to tenths of a second. The numbers of records used are shown in Table 2-1 by racecourse, racing distance, and track type.

Analysis of variance was done using the nested procedure (NESTED) of PC-SAS (1988). The completely nested model was adopted as follows: $y_{ijklmn} = \mu + t_i + g_{ij} + h_{ijk} + d_{ijkl} + r_{ijklm} + e_{ijklmn}$, where y_{ijklmn} an individual racing time of the n^{th} horse in the m^{th} race on the l^{th} day in the k^{th} month of the j^{th} year at the i^{th} racecourse, μ = the mean common to all observation, t_i = the effect of the i^{th} race course, g_{ij} = the effect of the j^{th} year at the i^{th} racecourse, h_{ijk} = the effect of the k^{th} month of the j^{th} year at the i^{th} racecourse, d_{ijkl} = the effect of the l^{th} day in the k^{th} month of the j^{th} year at the i^{th} racecourse, r_{ijklm} = the effect of the m^{th} race on the l^{th} day in the k^{th} month of the j^{th} year at the i^{th} racecourse, and e_{ijklmn} = random residual effect or the differences among horses in the same race. Assuming that all these effects except μ are random, the variance components for the sources of variation included in the model were estimated. Then the amount of variation was expressed as a percentage of the total variation.

Results and Discussion

Table 2-2 presents the means and standard errors of racing time for the race courses broken down by distance and track type . At all courses and at all distances where races were on both turf and dirt, racing times were less on turf than dirt. Using the average racing time over the race courses, the difference was 2.09s for 1000m, 2.46s for 1200m, 2.40s for 1400m, 2.55s for 1600m, and 3.91s for 1800m. There is consistent increase in the difference as distance increased

Table 2-1. Numbers of the racing records both on turf and dirt tracks by racecourse and race distance

Racecourse	Distance, m									
	1000		1200		1400		1600		1800	
	Turf	Dirt	Turf	Dirt	Turf	Dirt	Turf	Dirt	Turf	Dirt
Hakodate	1,117	1,132	2,978						2,726	
Fukushima	2,087	2,544							7,606	
Niigata	898	443	2,888		2,400		4,143		2,140	
Tokyo				3,726	4,026	5,967	5,092	8,384	4,182	
Nakayama			3,269	9,868			5,103		2,416	11,548
Chukyo		3,501	3,832						4,309	
Kyoto			2,647	5,064	4,193	6,440	6,195			8,133
Hanshin			2,191	8,286	3,142		5,962			10,082

Table 2-2. Means and standard errors of the racing time both on turf and dirt tracks by racecourse and race distance

Racecourse	Distance, m									
	1000		1200		1400		1600		1800	
	Turf	Dirt	Turf	Dirt	Turf	Dirt	Turf	Dirt	Turf	Dirt
Hakodate	60.68±.05	62.45±.04	72.71±.03						111.59±.05	
Fukushima	60.05±.03	61.75±.03							112.39±.02	
Niigata	60.10±.05	62.84±.06	72.33±.03		85.01±.03		97.60±.03		111.27±.03	
Tokyo				75.20±.03	85.61±.03	88.01±.03	98.43±.03	100.75±.02	111.52±.03	
Nakayama			71.68±.03	74.07±.02			97.63±.03		111.84±.04	115.64±.02
Chukyo		62.63±.02	72.13±.03						111.61±.03	
Kyoto			72.84±.03	75.20±.02	85.88±.03	87.83±.02	98.74±.03			115.33±.03
Hanshin			72.74±.03	75.32±.02	85.27±.03		98.37±.03			116.21±.02
Total	60.23±.02	62.32±.02	72.36±.01	74.82±.01	85.51±.02	87.91±.02	98.20±.01	100.75±.02	111.84±.01	115.75±.01

except for 1200m and 1400m. This difference in racing time between turf and dirt has not been reported in the literature reviewed.

Tables 2-3 and 2-4 show the percentages of the variation accounted for by sources in the hierarchy on turf and dirt, respectively. The tables include the total variance and residual variance at each distance. The total variance increases with distance on both turf and dirt and at each distance the total variance was larger on dirt than turf, except for 1000m, as was the residual variance. The total variance per 100m was $.20s^2$ at 1000m, $.23s^2$ at 1200m, $.21s^2$ at 1400m, $.24s^2$ at 1600m, and $.26s^2$ at 1800m on turf . The variance per 100m was $.19s^2$ at 1000m, $.26s^2$ at 1200m, $.28s^2$ at 1400m, $.28s^2$ at 1600m, and $.32s^2$ at 1800m on dirt. Buttram et al (1988) reported a total variance in Quarter horses at 796m of $1.43s^2$ which is $.18s^2$ per 100m. The American tracks are dirt, thus the variance per 100m appears to be much higher in the Japanese Thoroughbred data than that for American Quarter horses. The much shorter distances of Quarter horse does not spread the field of horses as is indicated in the longer Thoroughbred races in Japan.

Racecourses accounted for a small fraction of the total variance on turf (Table 2-3). They, however, appeared important as source variance at 1000m and 1200m on dirt (Table 2-4). These could be due to differences among courses in shape and/or location of the starting gate at these distance, especially on dirt. Buttram et al. (1988) reported large fractions of the total variance due to tracks from 10.6% to 31.8%. Greater uniformity between racecourses in Japan is suggested by these results.

Years within racecourses (Tables 2-3 and 2-4) appeared unimportant as a source of variation. Buttram et al. (1988) indicated year to account for from 5.2% to 7.8% of the total

Table 2-3. Percentages of variation accounted by racecourses, years, months, days, individual race and residuals to the total variance on turf track of Hakodate, Fukushima, Niigata, Tokyo, Nakayama, Chukyo, Kyoto, and Hanshin Racecourse

Source of variance	Distance, m									
	1000		1200		1400		1600		1800	
	df	%	df	%	df	%	df	%	df	%
Racecourses	2	5.0	5	6.5	3	3.7	4	5.7	5	3.2
Years	24	1.1	48	3.8	32	4.1	40	3.3	48	4.5
Months	54	16.7	203	6.8	178	9.2	241	13.1	197	17.7
Days	264	4.2	718	6.4	555	10.4	1,021	3.2	895	19.0
Races	127	18.8	672	39.1	444	35.4	1,050	44.9	1,057	27.8
Residual	3,630	54.2	16,158	37.4	12,548	37.2	24,138	29.8	21,176	27.8
Total variance	1.9655		2.7540		2.9502		3.8652		4.6316	
Residual variance	1.0659		1.0312		1.0960		1.1519		1.2897	

Table 2-4. Percentages of variation accounted by racecourses, years, months, days, individual race and residuals to the total variance on dirt track of Hakodate, Fukushima, Niigata, Tokyo, Nakayama, Chukyo, Kyoto, and Hanshin Racecourse

Source of variation	Distance, m									
	1000		1200		1400		1600		1800	
	df	%	df	%	df	%	df	%	df	%
Racecourses	3	13.0	3	14.1	1	.0	0	.0	2	2.7
Years	32	1.2	32	1.8	16	1.3	8	.0	24	2.5
Months	87	3.8	206	3.8	102	8.7	55	16.4	156	11.5
Days	311	3.4	902	6.7	459	.8	291	.0	849	1.3
Races	254	15.6	1,181	31.7	574	53.2	433	50.5	1,752	50.2
Residual	6,932	63.0	24,619	41.9	11,254	36.0	7,596	33.1	26,979	31.8
Total variance	1.9479		3.1473		3.8762		4.5548		5.6782	
Residual variance	1.2281		1.3189		1.3970		1.5076		1.8030	

variance. Year appears to be less important in the Japanese data.

Months within years and racecourses (Tables 2-3 and 2-4) accounted for an important fraction of the variance averaging 12.7% on turf and 8.8% on dirt. Months relate to seasons and the Japanese results suggest that season influences both the turf and the dirt tracks. This appear to be reasonable as seasons would influence the turf grass more than dirt.

Days within months, years, and racecourses (Tables 2-3 and 2-4) accounted for an average of 8.6% on turf and 2.4% on dirt. Comparing the sum of months and days which averaged 21.5% on turf and 11.2% on dirt with days in Buttram et al.(1988) show that the 14.7% for days in the Buttram study on dirt track is larger than the 11.2% on dirt in the Japanese data. Weather on a particular day appears to influence turf tracks more than dirt tracks.

Races within days, months, years, and racecourses (Tables 2-3 and 2-4) clearly shows that individual race differences contribute the most to the total variance. Averaged over the distances, 33.2% of the total variance is accounted for by race on turf and 40.2% for dirt. These value are larger than those reported by Buttram et al (1988). To remove as much non-genetic variance as possible before making genetic predictions for racing time requires the use of individual race as the contemporary group within which horses are compared. Using races as contemporary groups removes all other sources above races in the hierarchy. Addition of the percentages gives from 46% to 72% of the variance on turf and from 37% to 68% on dirt accounted for by using races as the contemporary groups. Since fixed effects can either be absorbed or fit easily using an animal model, the use of races as fixed effects is feasible.

The next step in the study of the genetics of racing performance in Japanese Thoroughbred is to examine the importance of non-genetic differences among horses in the same race. These differences include age and sex of the horse and the weight carried by the horse. These factors can be examined using an incomplete block analyses where blocks are races within which age, sex, and weight carried can be examined and correction factors developed. There remains the effect of jockey to be considered.

CHAPTER 3. INFLUENCE OF SEX, AGE AND WEIGHT CARRIED ON RACING TIME

Introduction

In Chapter 2, using individual races as fixed effects in an animal model was suggested as an appropriate way to make genetic and performance predictions on Japanese Thoroughbred horse for racing time. The next step involves development of correction factors or the inclusion of fixed effects for several non-genetic factors that are different among horses in the same race. These include sex, age, and weight carried. The effects of age, sex, and/or weight carried for racing time have been shown to be important in previous paper (Watanabe, 1969; Minkema, 1975; Rönningen, 1975; Hintz and Van Vleck, 1978; Katona, 1979; Hintz, 1980; Ojala and Van Vleck, 1981; Ojala, 1982; Tolley et al., 1983; Ojala et al., 1987; Buttram et al., 1988; Wilson, 1990). The purpose of this study is to examine the effects of sex, age, and weight carried on the racing time of Japanese Thoroughbred horses. This was done using an incomplete block design where individual races were the blocks, and sex-age effects and a linear regression for weight carried were fit.

Materials and Methods

The data for the within Chapter 1 were composed of five racing distances on turf track, i.e., 1200m, 1400m, 1600m, 1800m, and 2000m and on dirt track, i.e., 1000m, 1200m, 1400m, 1600m, and 1800m. Stallions and mares comprised the data since around .2% of the horses raced in Japan are geldings. Two-year old horses raced together (in the same race), and six-year old and older horses raced are around 5% of the horses raced in JRA. Therefore, age of horse was 3, 4 and 5 years. Only races having stallions and mares and more than two ages within sex were used. The numbers of records available and the number that met the criteria are given in Tables 3-1 and 3-2 for turf and dirt track, respectively. Finish time was measured to tenths of a second. Weight to be carried was measured to .5 k.

The analysis of variance and estimation of least squares constants was done using the incomplete block analysis (GLM) of PC-SAS (1990). The mathematical model was $y_{ijkl} = \mu + R_i + S_j + A_k + SA_{jk} + bF_{ijkl} + e_{ijkl}$, where y_{ijkl} = an individual racing time of the ijklth horse in the ith race, of the jth sex, the kth age, and carrying the ijklth weight, μ = the mean, R_i = the effect of the ith race or block, S_j = the effect of the jth sex, A_k = the effect of the kth age, SA_{jk} = the interaction effect of the jth sex and the kth age, b = linear partial regression coefficient of racing time on weight carried, F_{ijkl} = the weight carried by the ijklth horse, e_{ijkl} = random residual error. All effects were considered fixed except for the error.

Results and Discussion

The edit of data reduced the numbers available, but the numbers were adequate to get estimates as shown in Tables 3-1 and 3-2.

Tables 3-3 and 3-4 give the analysis of variance for turf and dirt track, respectively. On both turf and dirt, the individual race effects were highly significant at all distances. The two tables clearly indicate that the interaction between age and sex was unimportant for racing time but significant (P=.049) at 1200m on dirt. The effect of sex was highly significant for the three shortest distances, 1200m, 1400m and 1600m, on turf tracks. Sex was significant for the three longest distances, 1400m, 1600m and 1800m, on dirt tracks. The effect of age (3, 4, and 5 year olds) was highly significant at 1600m and significant at 1200m on turf. Age was highly significant at all of the distances except

Table 3-1. Numbers of racing time records and numbers used in the analysis of sex, age, and weight carried on turf track

Sex	Distance, m														
	1200			1400			1600			1800			2000		
	3[a]	4	5	3	4	5	3	4	5	3	4	5	3	4	5
Female	7,019[b]	2,507	901	4,751	1,320	473	7,874	2,917	1,258	9,523	4,074	1,361	6,221	3,159	1,375
	1,266[c]	1,539	681	588	733	326	1,003	1,440	732	1,335	1,699	711	872	1,395	757
Male	5,415[b]	2,218	910	3,907	1,303	546	8,628	3,237	1,538	11,976	5,514	2,349	13,614	6,482	3,293
	1,095[c]	1,483	718	665	853	409	1,500	1,968	1,016	2,115	2,691	1,188	1,984	2,717	1,386

[a] The figures 3, 4 and 5 corresponds to the ages for horses.

[b] Total observations before edited.

[c] Edited observations.

Table 3-2. Numbers of racing time records and numbers used in the analysis of sex, age, and weight carried on dirt track

Sex	Distance, m														
	1000			1200			1400			1600			1800		
	3[a]	4	5	3	4	5	3	4	5	3	4	5	3	4	5
Female	3,390[b]	952	164	11,185	2,338	915	3,633	1,450	565	2,790	1,160	484	8,467	3,854	1,882
	397[c]	459	111	850	1,378	621	359	625	319	178	379	217	624	1,177	779
Male	2,972[b]	1,004	252	9,923	2,360	1,067	4,067	1,622	895	4,136	1,916	944	13,558	6,952	4,145
	348[c]	565	160	942	1,592	786	637	880	549	358	722	386	1,440	2,600	1,547

[a] The figures 3, 4 and 5 corresponds to the ages for horses.

[b] Total observations before edited.

[c] Edited observations.

Table 3-3. Analysis of variance for racing time on turf track by racing distance

Source of variance	Distance, m									
	1200		1400		1600		1800		2000	
	df[a]	MS[b]	df	MS	df	MS	df	MS	df	MS
Race	592	18.94**	308	16.01**	671	22.53**	901	38.80**	852	38.20**
Sex	1	11.84**	1	11.81**	1	27.88**	1	1.26	1	3.20
Age	2	1.95*	2	.08	2	5.48**	2	2.38	2	1.48
Sex * Age	2	1.34	2	.26	2	.63	2	1.56	2	.46
Weight carried	1	14.09**	1	22.00**	1	56.40**	1	20.79**	1	47.95**
Error	6,183	.62	3,259	.61	6,981	.73	8,831	1.00	8,252	1.06

* $p < .05$, ** $p < .01$.

[a] df means the degrees of freedom.

[b] MS means the mean squares.

Table 3-4. Analysis of variance for racing time on dirt track by racing distance

Source of Variance	Distance, m									
	1000		1200		1400		1600		1800	
	df[a]	MS[b]	df	MS	df	MS	df	MS	df	MS
Race	176	11.65**	535	12.80**	303	14.71**	214	28.21**	747	27.01**
Sex	1	1.34	1	.00	1	5.13*	1	4.83*	1	35.51**
Age	2	9.38**	2	6.85**	2	.43	2	5.37**	2	12.49**
Sex * Age	2	.28	2	2.28*	2	1.62	2	1.15	2	2.07
Weight carried	1	8.36**	1	3.77*	1	13.56**	1	4.08*	1	21.90**
Error	1,857	.96	5,627	.76	3,059	.95	2,019	1.05	7,413	1.40

* $p < .05$, ** $p < .01$.

[a] Means the degrees of freedom.

[b] Means the mean squares.

1400m on dirt. In the shorter three distances on turf the main effect for sex of horse appears to be slightly more important than age, the effect of sex and age, however, was unimportant on 1800m and 2000m. On dirt, the effect of sex and/or age was important. The linear regressions for weight carried at each distance on turf were highly significant. On dirt they were highly significant at 1000m, 1400m and 1800m, and were significant at 1200m and 1600m.

Tables 3-5 and 3-6 give the least squares means and constants for sex and age of the horses at distance for turf and dirt, respectively. Mares were faster on turf than stallions at each distance on turf. Stallions, however, were faster at 1000m, 1400m, 1600m, and 1800m but slower than mares at 1200m on dirt. The differences showed no trend with distance of the race on turf or dirt. The overall effects of sex was not large in the Japan Thoroughbred.

At the 796m distance for Quarter horses in Buttram et al.(1988), stallions were faster than mares using marginal means (.321). Both differences in Japanese Thoroughbreds at 1000m on dirt are one fourth (.09) of the magnitude of the same effect in Quarter horses. For North-Swedish trotters, males were faster than females using the least-squares mean of highest trotting time (Rönningen, 1975). Means of best time for males in Finnish horses were superior to them for females in 4 and 5 age groups and these differences were 1.4s and .6s, respectively (Ojala, 1982). And also Ojala et al.(1987) reported that stallions were faster than mare, but the differences of sex were nonsignificant by using racing time in seconds per kilometer. Only at the longer distances on turf did the stallions approach the mares and on dirt the stallions were faster than the mares except at 1200m. The trend of sex on dirt was as same as it in Quarter horse and Trotter.

Tables 3-5 and 3-6 give the age differenced for 3, 4, and 5

Table 3-5. Least-squared means and constants for sex, age, and the partial regression coefficients for weight carried on turf

Source		Distance, m									
		1200		1400		1600		1800		2000	
		LSM[a]	Estimate	LSM	Estimate	LSM	Estimate	LSM	Estimate	LSM	Estimate
Sex	Female	71.48	.0	84.23	.0	96.94	.0	111.42	.0	124.09	.0
	Male	71.61	.199**	84.40	.216**	97.12	.205**	111.46	.096	124.14	.052
Age	3	71.55	.086	84.30	.008	96.96	-.073	111.48	.147**	124.15	.084
	4	71.58	.111**	84.32	.030	97.09	.074	111.45	.088	124.12	.028
	5	71.52	.0	84.32	.0	97.04	.0	111.39	.0	124.08	.0
Partial regression coefficient			-.049**		-.084**		-.087**		-.050**		-.068**

[a] Least-squared mean

* p<.05 ** p<.01

Table 3-6. Least-squared means and constants for sex, age, and the partial regression coefficients for weight carried on dirt

Source		Distance, m									
		1000		1200		1400		1600		1800	
		LSM[a]	Estimate	LSM	Estimate	LSM	Estimate	LSM	Estimate	LSM	Estimate
Sex	Female	61.74	.0	73.65	.0	86.72	.0	100.05	.0	114.75	.0
	Male	61.65	-.149	73.67	.065	86.63	-.044	99.90	-.127	114.57	-.123*
Age	3	61.91	.370**	73.69	.118*	86.70	.069	100.13	.359**	114.75	.240**
	4	61.69	.133	73.72	.196**	86.68	.112	99.95	.084	114.68	.191**
	5	61.50	.0	73.58	.0	86.64	.0	99.84	.0	114.55	.0
Partial regression coefficient			-.065**		-.025*		-.064**		-.041*		-.505**

[a] Least-squared mean

* $p<.05$ ** $p<.01$

year olds. The age effects were not consistent over distances on turf. At 1200m, 1800m, and 2000m, 5 year olds were the fastest, but at 1400m and 1600m 3 year olds were fastest. On dirt at all distances the 5 year olds were the fastest.

For the 796m distance in Quarter horses in Buttram et al.(1988), 3 year olds were faster than 4 year olds and 5 year olds were slower than 4 year olds. In Rönningen (1975), 5 year olds were faster than 3 year olds, and 4 year olds for Finnish horses were faster than 3 year olds (Ojala, 1982). In our data at 1000m on dirt, 5 year olds were faster than either 3 and 4 year olds. At 1200m on turf, 3 year olds were faster than 4 year olds and 5 year olds were faster than either 3 or 4 year olds. The effect of age appears to be different for turf and dirt.

Tables 3-5 and 3-6 also given the partial linear regression coefficients for racing time on weight carried on turf and dirt, respectively. The sign was negative at all distances on both turf and dirt. The values on the same distance were smaller on dirt compared with turf except at 1200m and all coefficient were highly significant except at 1200m and 1600m on dirt where it was only significant. These coefficients in Japan Thoroughbreds are much higher than those found for the Quarter horse by Buttram, et.al.(1988). Also the linear regressions reported by Wilson (1990) are in general smaller for the Quarter horse. However, Wilson (1990) found the quadratic regression to be more appropriate than the linear for the 365m and 402m distances.

The comparisons between the Quarter horse and the Thoroughbred have the difficulty that the analyses procedures were different. The comparisons suggest that in the longer distances run by Thoroughbreds that mares are faster than stallions except at the longer distances on dirt where in Quarter horse the stallions are faster than the mares at 796m.

Large number of mares are retired from racing as 3 and 4 year olds for use in breeding where a small number of stallions are retired but not until they are 4, 5, and 6 year olds in the Japanese data (Chapter 1). The age effects appear different also. In the thoroughbred data, the speed appears in general to increase with age up to 5 years especially on dirt. The magnitude of the age effects are in general larger in Thoroughbreds than at the shorter distances run by Quarter horses.

CHAPTER 4. INFLUENCE OF JOCKEY ON RACING TIME IN THOROUGHBRED HORSE

Introduction

There are many factors affecting racing time of horses. Chapter 2 and 3 elucidated that individual races, sex, age, and weight carried should be considered as fixed effects to make genetic and performance predictions in Thoroughbred horses for racing time. Although jockey was considered to be an important factor, the jockey effect was not included because of the limitation of the data structure. Preisinger et al. (1990) reported that the heritability estimate for earnings per start decreased as the jockey effect was excluded from the analysis. The merit of horses and jockeys are related, because as the reputation of a jockey increases the jockey has the opportunity to ride better horses. Therefore, horse and jockey effects need to be considered simultaneously. The data used by Chapter 3 did not have enough connectedness between horse and jockey to allow for simultaneous estimation.

The connectedness between jockey and horse ensues when each jockey rides more than one horse and vice versa. The use of the numerator relationship matrix would increase the connectedness in the mixed model equations (Dempfle, 1990). This results because horses that are related can increase the connectedness. Lin et al. (1984) tested for significance of fixed effects in the mixed model analysis, based on Searle's algorithm (1971).

The purpose of this study is to examine the effect of jockey on racing time of horses at different racing distances on turf and dirt tracks in Thoroughbred horses.

Materials and Methods

Records on individual animal racing times for flat races at the Sapporo, Hakodate, Fukushima, Niigata, Nakayama, Tokyo, Chukyo, Kyoto, Hanshin and Kokura racecourses from 1988 to 1990 were obtained from the Japan Racing Association (JRA). The data were composed of five racing distances on turf track, i.e., 1200m, 1400m, 1600m, 1800m, and 2000m and on dirt track, i.e., 1000m, 1200m, 1400m, 1600m, and 1800m. Ages of the horse were 3, 4 and 5 years. The records of horses that were off at the finish line for a definition reason, i.e., nasal bleeding, atrial fibrillation and etc., were excluded. Only races having more than two ages represented were used. Furthermore, the data were edited to ensure that all jockeys were connected with all horses. For connectedness between jockey and horse, firstly horses were related with one jockey who rode on the most horses, secondly these horse related were connected with jockeys, thirdly these jockey related were connected with horses and this proceeded until horses and jockeys were connected. Then all jockeys who connected with all horses were selected. The edited data finally were satisfied both conditions, i.e., two more ages among race and the connectedness between jockeys and horses.

Final data set used in this analysis was shown in Table 4-1. For each type of track and distance run, the number of jockeys before editing for connectedness averaged 230 and after editing averaged 211. The number of horses before editing averaged 3180 and after editing averaged 2905.

The mathematical model was $y_{ijklm} = \mu + R_i + A_j + J_k + h_l + bF_{ijklm} + e_{ijklm}$, where y_{ijklm} = an individual racing time, μ = the overall mean, R_i = the effect of the i^{th} race, A_j = the effect of the j^{th} age, J_k = the effect of the k^{th} jockey, h_l = the effect of the l^{th} horse, b = linear regression of racing time on weight carried, F_{ijklm} = a particular weight carried by the l^{th} horse, and e_{ijklm} = random residual effect. All effects except horse and residual were fixed. The jockey effects are

Table 4-1. Number of jockeys and individual horses by racing distances and types of tracks track

Types of Tracks	Racing Distance	Number of Jockeys		Number of Individual horses	
		Before editing	After editing	Before editing	After editing
Turf					
	1200m	246	237	3,182	3,036
	1400m	227	198	2,290	2,054
	1600m	258	238	3,622	3,322
	1800m	248	238	4,349	4,042
	2000m	245	229	3,894	3,573
Dirt					
	1000m	219	198	2,058	1,914
	1200m	241	233	4,171	3,872
	1400m	233	186	2,449	2,076
	1600m	145	118	1,680	1,430
	1800m	240	232	4,101	3,729

the particular effects to fit simultaneously in the genetic analysis. Horses were assumed to have $N(0, A\sigma_a^2)$, where A is the numerator relationship matrix among horses and residual effects were assumed to have $N(0, I\sigma_e^2)$.

The mixed model equations (Henderson, 1984) are of the form:

$$\begin{bmatrix} X'X & X'Z \\ Z'X & Z'Z + A^{-1}\sigma_e^2/\sigma_a^2 \end{bmatrix} \begin{bmatrix} b \\ u \end{bmatrix} = \begin{bmatrix} X'y \\ Z'y \end{bmatrix}$$

where b is a generalized least-squares solution. The hypothesis testing ($H: K'b = 0$) of the fixed effects in the mixed model was carried out based on the following algorithm (Searle, 1971):

$F = Q/(q\sigma_e^2)$, where the F statistic has q and N-r(X) d.f., r(X) = rank of X, $Q = (K'b)'[K'C_{11}K]^{-1}(K'b)$, q = rank of $K'C_{11}K$, K' = full row rank, and C_{11} = sub matrix for the fixed effects from $\begin{bmatrix} C_{11} & C_{12} \\ C_{12} & C_{22} \end{bmatrix} = \begin{bmatrix} X'X & X'Z \\ Z'X & Z'Z + A^{-1}\sigma_e^2/\sigma_a^2 \end{bmatrix}^{-}$.

The additive genetic variance (σ_a^2) and environmental variance (σ_e^2) for racing time used in this study were estimated based on animals' additive genetic model by the MTDFREML program (Boldman et al., 1993) which was modified from Meyer's (1988a, 1988b, 1989) DFREML that included SPARSPAK (Boldman and Van Vleck, 1991). The derivative-free REML algorithm suggested by Graser et al.(1987) was used. REML was first described in terms of mixed-model equations by Patterson and Thompson (1971).

Initial variance ratio (σ_e^2/σ_a^2) was estimated to be .93, .97, .88, .82, and .77 in 1200m, 1400m, 1600m, 1800m and 2000m, respectively, on turf and .49, .61, 1.11, 1.26 and .46 in 1000m, 1200m, 1400m, 1600m and 1800m, respectively, on dirt track. These were the values used in the analysis.

Results and Discussion

The sex effect was an important effect for analysis of racing time (Chapter 3). However, if the connectedness between jockey and horse was edited by our conditions, the data edited became a few. Furthermore, horses are nested within the sex and then the latter effect is included in the former which is taken up in the mathematical model. By these reasons, we omitted the sex effect from mathematical model. However, the sex effect is needed to evaluate the Thoroughbred horse.

The use of the numerator relationship matrix generally strengthens the connectedness between jockeys and horses. However, the numerator relationship matrix would increase the order of the coefficient matrix and thus the computing time.

The significance of the jockey effect tested either with or without the pedigree information traced back two generations were compared at 1400m on both turf and dirt tracks (Table 4-2). The significance level of all effects was not changed by ignoring the pedigree information. As the data were edited to ensure the connectedness between jockeys and horses, and the average inbreeding coefficients among horses were low, i.e., .0156 on turf and .0469 on dirt, the numerator relationship matrix could be regarded as the identity matrix in this case.

Tables 4-3 and 4-4 give the results of hypothesis testing for the significance of fixed effects and the variance components on racing time on turf and dirt tracks, respectively. The jockey effect on racing time, which was main concern in this study, was highly significant ($P<.01$) at all racing distances on both turf and dirt tracks. The percentages of the variance accounted for by the jockey effect were from .7% to 1.0% on turf and from .8% to 1.9% on dirt track. The values of the percentage were not changed on turf while

Table 4-2. Mean squares and significance levels with and without the use of the pedigree information in 1400m race on turf and dirt tracks

Source	Turf track			Dirt track		
	df[a]	Without pedigree	With pedigree	df	Without pedigree	With pedigree
		MS[b]	MS		MS	MS
Race	176	9.485**	9.950**	184	6.683**	6.946**
Age	2	.110	.173	2	.347	.628
Jockey	145	.645**	.665**	140	.917**	.890**
Weight	1	4.671**	5.406**	1	11.121**	13.224**
Error	1,567	.488	.510	1,472	.562	.587

* P < .05, ** P < .01.

[a] df means the degree of freedom.

[b] MS means the mean squares.

Table 4-3. Analysis of variance for racing time by racing distances on turf track

Source	1200				1400				1600				1800				2000			
	df	MS	Vc	%	df	MS	Vc	%	df	MS	Vc	%	df	MS	Vc	%	df	MS	Vc	%
Horse	3,035	1.605**	.478	29.3	2,053	1.312**	.513	29.5	3,321	1.702**	.617	27.8	4,041	2.232**	.739	23.8	3,572	3.166**	.960	24.1
Race	604	8.899**	.694	42.5	281	8.751**	.714	41.1	547	12.347**	1.037	46.7	836	19.063**	1.738	56.0	859	24.443**	2.256	56.6
Age	2	.597	.000	0.0	2	.125	-.000	0.0	2	.083	-.000	0.0	2	1.048	.000	.0	2	.603	-.000	.0
Jockey	236	.977**	.017	1.0	197	.723**	.014	.8	237	1.117**	.022	1.0	237	1.387**	.021	.7	228	1.928**	.030	.7
Weight	1	.544			1	7.359**			1	8.416**			1	16.922**			1	1.403**		
Error	6,527	.445	.445	27.2	2,779	.498	.498	28.6	5,451	.543	.543	24.5	7,811	.607	.607	19.5	7,944	.740	.740	18.6

Distance, m

* P < .05, ** P < .01.

Table 4-4. Analysis of variance for racing time by racing distances on dirt track

Source	Distance,m																			
	1000				1200				1400				1600				1800			
	df	MS	Vc	%	df	MS	Vc	%	df	MS	Vc	%	df	MS	Vc	%	df	MS	Vc	%
Horse	1,913	2.060**	.802	52.1	3,871	2.344**	.854	45.2	2,075	1.446**	.542	27.8	1,429	1.783**	.588	26.2	3,728	4.529**	1.616	46.3
Race	374	3.832**	.326	21.2	726	6.150**	.495	26.2	308	8.709**	.775	39.7	245	9.731**	.873	38.9	833	12.295**	1.103	31.6
Age	2	1.690*	.001	.0	2	3.018**	.001	.0	2	.296	-.000	.0	2	1.370	.001	.0	2	1.634	.000	.0
Jockey	197	.777**	.019	1.2	232	1.267**	.021	1.1	185	1.165**	.033	1.7	117	1.674**	.044	1.9	231	1.753**	.027	.8
Weight	1	1.163			1	5.384**			1	21.649**			1	25.079**			1	3.151**		
Error	3,404	.393	.393	25.5	7,302	.521	.521	27.5	2,738	.602	.602	30.8	2,169	.741	.741	33.0	7,669	.744	.744	21.3

* $P < .05$, ** $P < .01$.

increased on dirt as the racing distance increased between 1000m and 1600m. This suggested that the jockey skill was more important on dirt track than on turf.

Table 4-5 reports the range found in jockey effects for different distances on both turf and dirt tracks. The range in jockey effects averaged -.68 to 2.87 over all distances and type of track. The difference between the jockey with the least average seconds and the most average seconds was 3.55 seconds which is as large effect when compared to the error standard deviation. The range roughly would the 5 times the standard deviation. There is an indication that range decreases to 1600m on turf and 1400m on dirt and then increases with distance on both tracks. This is also apparent in the magnitude of the mean squares for the jockey effects.

The individual race effects also were highly significant at all racing distances and the percentages of variance accounted for by the race effect were from 41.1% to 56.6% on turf and from 21.2% to 39.7% on dirt. These results indicate that the race effect is the most important of the fixed effects. The rates were larger on turf than on dirt and these percentages in shorter distances were smaller than in longer distances on both tracks. The linear regression of racing time on weight carried was highly significant except for 1200m on turf and 1000m on dirt. The significant effects of race and weight carried on racing time were similar to those reported by Chapter 2 and 3.

On turf track, age was not a significant factor over different racing distances studied (Table 4-3). However, on dirt track, age effect was found to be significant over shorter races (1000m and 1200m) but not significant over longer races (1400m, 1600m and 1800m) (Table 4-4). In contrast, Chapter 3 reported that age was an important factor on both turf and dirt tracks.

Table 4-5. The range found in jockey effects for different distances on both turf and dirt tracks

Distances	Turf	Dirt
1000m		-1.94 to +1.66
1200m	- .86 to +2.55	-1.05 to +2.63
1400m	- .08 to +3.13	-1.63 to +1.41
1600m	- .50 to +2.52	-1.99 to +1.82
1800m	-1.74 to +2.69	-1.01 to +2.97
2000m	+3.99 to +7.36	

In general, the influence of the jockey skill on racing time becomes more important as the racing distance increases, especially on dirt track. Sex and age effects were included in the previous model (Chapter 3), while age and jockey effects with horse effects were included in this study omitting sex effect. These results suggest that the jockey effect is important on racing time.

On the basis of the results of this study and the previous one (Chapter 2 and 3), it is concluded that individual race, sex, age, jockey and weight carried should be taken into account to make genetic and performance prediction on racing time in the Thoroughbred horse.

CHAPTER 5. GENETIC PARAMETER ESTIMATES FOR RACING TIME BY RESTRICTED MAXIMUM LIKELIHOOD IN THOROUGHBRED HORSE OF JAPAN

Introduction

Estimation of genetic parameters for racing time in the Thoroughbred horse has been reported by Artz (1961), Bormann (1966) and Watanabe (1969). These estimates were based on the paternal half sib and/or the offspring-dam regression method. Recently, the restricted maximum likelihood (REML) method has one of the most desirable statistical properties for the estimates of variance components. Genetic parameter estimates of horse by REML were given by Buttram et al. (1988) and Huizinga et al. (1990, 1991). The estimation of genetic parameters for racing time by REML in the Thoroughbred horse has not been reported.

The pedigree information is an important element in the estimation of genetic variance and covariance by the REML. It strengthen connectedness between animal and the fixed effect. If the pedigree information is increased without limit, the cost for computation will increase. The preferable generation for estimation of the genetic parameter needs to be considered.

The purpose, of this study is to optimize the amount of the pedigree information or determine to which generation pedigrees should be traced and then to estimate genetic parameters for repeated racing times on the same horse by racing distance on both turf and dirt in the Thoroughbred horse.

Materials and Methods

Individual animal racing times for flat races at the Sapporo, Hakodate, Fukushima, Niigata, Nakayama, Tokyo, Chukyo, Kyoto, Hanshin and Kokura racecourses from 1986 to 1990 were obtained from the Japan Racing Association (JRA). The data were composed of six racing distances on turf track, i.e., 1000m, 1200m, 1400m, 1600m, 1800m, and 2000m and of five on dirt track, i.e., 1000m, 1200m, 1400m, 1600m, and 1800m. Mare and stallion were included. The records of horses that were off at the finish line were deleted as given by Chapter 2, 3 and 4.

Variance components were estimated by assuming the following model:

$$y = X\beta + Za + Zp + e$$

where y = vector of records, β = vector of fixed race, sex, age, jockey and weight carried effects (Chapter 2, 3 and 4) as associated with records in y by X, a = vector of additive genetic effects as associated with records in y by Z, p = vector of permanent environmental effects as associated with records in y by Z, e = vector of residual effects, and X and Z are incidence matrices relating a particular record to a particular individual.

Genetic parameters were estimated by the MTDFREML program (Boldman et al., 1993) which was modified from Meyer's (1988a, 1988b, 1989) DFREML that included SPARSPAK (Boldman and Van Vleck, 1991). The derivative-free REML algorithm suggested by Graser et al.(1987) was used. REML was first described in terms of mixed-model equations by Patterson and Thompson (1971).

In all sets of data for repeated records on the same horse, initial values were .20 for genetic variance, .50 for permanent environmental variance and .50 for temporary environmental variance. The convergence criterion value was set to $1x10^{-9}$.

The pedigree information was traced back to generation 1 (sire and dam), generation 2, generation 3, generation 4, and generation 5 in the 1600m distance on turf and dirt track.

Heritability was estimated by dividing the genetic variance by the total phenotypic variance. Repeatability was estimated by dividing the sum of the genetic variance and the permanent environmental effects by the total phenotypic variance.

Results and Discussion

Tables 5-1 and 5-2 show the variances and heritabilities estimated, number of observations, number of animals concerned when pedigree was traced back from one to five generations at 1600m on turf and dirt tracks, respectively.

When the amount of pedigree information increased from generation 1 to generation 2, the genetic variance decreased, while the permanent environmental variance increased both on turf and dirt tracks. However, from generation 2 to generation 5, they were almost unchanged. The temporary environmental and phenotypic variances did not change. As a result, the heritability estimate was highest with the pedigree of generation 1, but almost the same from generation 2 to generation 5.

In general, the additive genetic variance declines due to the directional selection. Van der Werf and Boer (1990) indicated that REML with all relationships traced back to a base population concerned would estimate the genetic variance in the implied base population. However, the genetic variance was largest with generation 1, and change in the permanent environmental variance was complementary to that of the genetic variance since the variance attributable to each is used to separate them. The genetic variance and therefore the heritability seem to be overestimated with pedigrees traced only one generation. On the other hand, number of animals included and CPU time for analysis increased in proportion to the generation number. It is suggested that the generation 2

Table 5-1. Estimates of variance, heritability and repeatability, CPU time for analysis, numbers of animals concerned and inbreeding coefficient with pedigree information traced back to generation 1, generation 2, generation 3, generation 4 and generation 5 at 1600m on turf track

Item	Generations 1	2	3	4	5
Genetic variance	.197	.160	.157	.166	.166
Permanent environmental variance	.573	.609	.613	.606	.606
Temporary environmental variance	.554	.554	.554	.554	.554
Phenotypic variance	1.325	1.323	1.324	1.326	1.327
Heritability	.149	.121	.118	.125	.126
Repeatability	.581	.581	.582	.582	.582
CPU time for analysis[a]	1:47:10	3:01:28	5:01:48	7:08:32	10:40:14
No. of different animals	13,170	17,365	20,627	23,342	25,566
No. of inbred animals	0	46	2,153	10,632	16,278
Average inbreeding coefficient	.0	.0251	.0105	.0085	.0123

[a] hour:minute:second

Table 5-2. Estimates of variance, heritability and repeatability, CPU time for analysis, numbers of animals concerned and inbreeding coefficient with pedigree information traced back to generation 1, generation 2, generation 3, generation 4 and generation 5 at 1600m on dirt track

	Generations				
Item	1	2	3	4	5
Genetic variance	.160	.127	.129	.136	.139
Permanent environmental variance	.665	.698	.696	.691	.689
Temporary environmental variance	.659	.659	.658	.658	.658
Phenotypical variance	1.483	1.483	1.484	1.485	1.486
Heritability	.108	.086	.087	.092	.094
Repeatability	.556	.556	.556	.557	.557
CPU time of analysis[a]	15:36	25:35	43:55	1:14:16	2:02:44
No. of different animals	5,814	8,470	10,884	13,061	14,953
No. of inbred animals	0	6	751	3,993	7,625
Average inbreeding coefficient	.0	.0286	.0116	.0089	.0118

[a] hour:minute:second

pedigree information is preferable for analysis of variance estimates as Lejukole et al. (1993) and Oikawa et al. (1994) indicated.

Tables 5-3 and 5-4 show the same information as Tables 5-1 and 5-2 when the pedigree information was traced back to generation 2 by racing distances on turf and dirt tracks, respectively. The temporary environmental variance increased as the racing distance increased from 1000m to 1800m, while the genetic variance tended to decrease especially on turf. The heritability estimate decreased from .25 to .08 on turf track as the racing distance increased (Table 5-3). The estimate had the same tendency, on dirt track.

The heritability estimates for racing time were reported by some researchers: .116 at 1600m in the Thoroughbred horse of Japan (Watanabe, 1969), .29 at 1.6km in Standardbred (Tolley et al., 1983), and .38 at 201m and .20 at 796m in American Quarter horse (Buttram et al., 1988). Comparing with the heritability estimate at 796m in American Quarter horse, the present result at 1000m on dirt was the same. Furthermore, it supports the same tendency that the higher heritability was estimated at the shorter distance in this study.

The average of race records per horse for 3 year olds and up was 6.7 (Chapter 1). This indicates that the same horse ran at the different racing distances. On the other hand, the heritability seems to decrease as the racing distance increases. These facts suggest that racing times at the different racing distances may be regarded as different traits when the horse is to be evaluated genetically. But the genetic correlations are necessary to determine this. As distance increases, more factors, probably environmental in nature, are influencing the racing speed.

The sum of the genetic variance plus the permanent environmental variance divided by the phenotypic variance is

Table 5-3. The number of observations and the genetic, environmental and phenotypic variances, heritability, and repeatability estimated with the pedigree information traced back to generation 2 on turf track by racing distances

	Racing distance, m					
Item	1000	1200	1400	1600	1800	2000
No. of observations	2,990	16,938	8,451	15,277	17,743	18,244
Genetic variance	.324	.186	.106	.160	.140	.131
Permanent environmental variance	.569	.484	.453	.609	.557	.814
Temporary environmental variance	.383	.488	.544	.554	.917	.670
Phenotypic variance	1.276	1.157	1.103	1.323	1.614	1.614
Heritability	.254	.160	.096	.121	.087	.081
Repeatability	.700	.579	.507	.581	.432	.586

Table 5-4. The number of observations and the genetic, environmental and phenotypic variances, heritability, and repeatability estimated with the pedigree information traced back to generation 2 on dirt track by racing distances

Item	Racing distance, m				
	1000	1200	1400	1600	1800
No. of observations	7,021	18,574	7,210	5,429	18,330
Genetic variance	.260	.325	.156	.127	.386
Permanent environmental variance	.650	.640	.501	.698	1.185
Temporary environmental variance	.450	.530	.633	.659	.769
Phenotypic variance	1.360	1.496	1.290	1.483	2.340
Heritability	.191	.217	.121	.086	.165
Repeatability	.669	.645	.509	.556	.671

repeatability. It is a measure of how repeatable the racing performance of a horse is. These values appear in Tables 5-3 and 5-4. That is around 60% of the difference among racing performance of horses can be expected to occur next year, for example. Such "horse values" could be a valuable information to adjust the handicapping procedure of JRA. The PEV is probably influenced by differences in training of the horses.

CHAPTER 6. ESTIMATION OF GENETIC TREND OF THOROUGHBRED HORSE IN JAPAN

Introduction

In Japan, the history of breeding for the Thoroughbred horse is short. In 1941, the number of horses born in a year totaled only 473. However, they began to increase from the latter half the 1960s and reached 7,662 in 1987 (Japan Bloodhorse Breeders Association, 1992). Five sires and twelve dams were imported in 1952 and then until 1992, 708 sires and 3173 dams in total were imported. The foreign-sire has contributed to improve the Japanese Thoroughbred horse. In fact, six of the top ten leading sires for 1991 were grouped as the foreign-sire. However, since most of sires and dams in Japan were domestic-sire and domestic-dam, it is important to know how the foreign-sires and foreign-dams were influenced on racing performance of the Thoroughbred breeding in Japan.

The Thoroughbred horse in Japan race at Japan Racing Association (JRA) and Local Association of Racing, and 3,656 horses were registered to JRA among 6,964 foals registered in 1984 (Chapter 1). By this reason, it is important for Japanese horse breeders to know the genetic trend of horses at JRA.

The purpose of this study are to predict the breeding value of the Thoroughbred horse and to estimate the genetic trend for racing time and evaluate influence of foreign-sire and foreign-dam on it.

Materials and Methods

Individual animal racing times for flat races at ten race-courses from 1975 to 1993 were obtained from Japan Racing Association (JRA). The data were composed of 1600m racing distance on turf and dirt track used as Chapter 5.

The breeding value were predicted by the best linear unbiased prediction (BLUP) using MTDFREML program (Boldman et al., 1993).

A model was assumed as follows:

$$y = X\beta + Za + Zp + e$$

where y = vector of records, β = vector of fixed race, sex, age, jockey and weight carried effects (chapter 2, 3, 4) as associated with records in y by X, a = vector of additive genetic effects as associated with records in y by Z, p = vector of permanent environmental effects as associated with records in y by Z, e = vector of residual effects, and X and Z are incidence matrices relating a particular record to a particular individual.

The pedigree was traced back to generation 2 from the particular horse and the numerator relationship was calculated as in Chapter 5.

Genetic trend for racing time was computed as averages of the breeding value for horses born in the particular year.

Results and Discussion

The means of racing time by birth year were shown at Figure 6-1 on turf and dirt tracks. The means were up and down on both tracks but, became better generally as birth year. After 1988, means of racing time on turf and dirt track, however, were worse. One of these reasons might be the rebuilt of track at a racecourse, especially in Hanshin racecourse from 1990 to 1991. The trend of means of racing time on dirt was better than it on turf.

Figure 6-2 shows that the mean of breeding value became better on turf and dirt tracks as birth year . This results suggest that the genetic improvement was advanced in Japan. We are interested in whether the genetic improvement depends on the introduction of foreign sires and dams. The numbers of foreign-sires and foreign-dams decreased as the birth year of

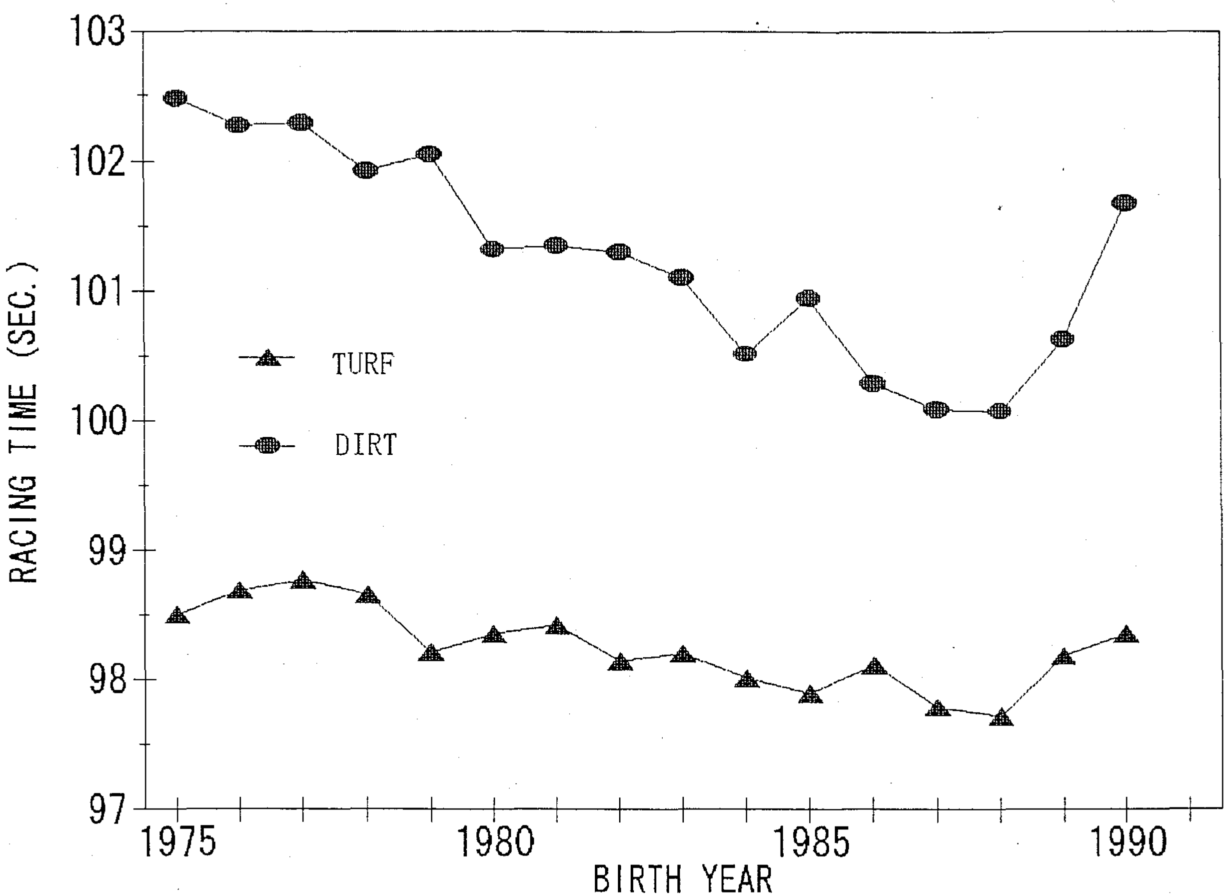

Figure 6-1. Trends of simple mean for racing time by birth year at 1600m on turf and dirt tracks

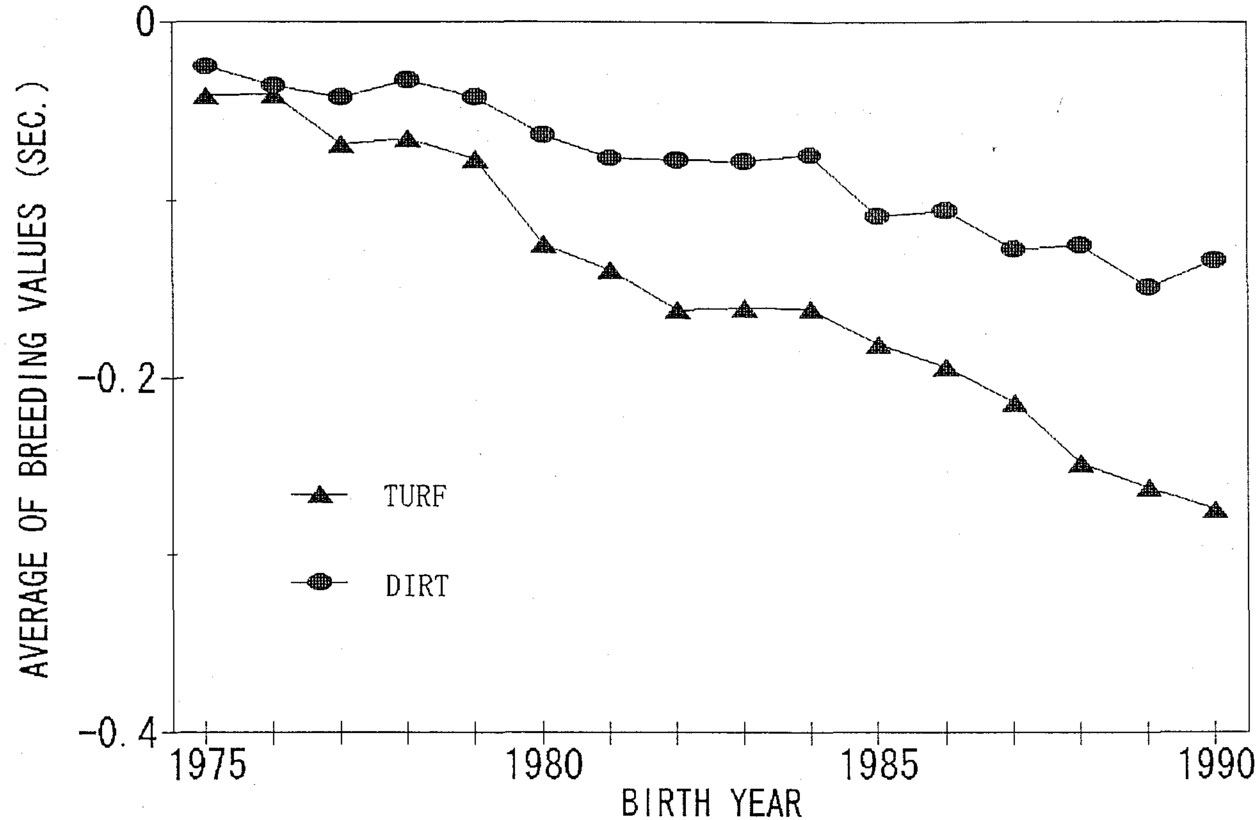

Figure 6-2. Genetic trends for racing time at 1600m on turf and dirt track in Thoroughbred horses

foals went on (Table 6-1). However, Tables 6-2 and 6-3 show the summary of four combinations (domestic-sire & domestic-dam, domestic-sire & foreign-dam, foreign-sire & domestic-dam and foreign-sire & foreign-dam) of sire and dam by their birth area and foal's birth year at 1600m on turf and dirt track, respectively. The numbers of domestic-sire & foreign-dam, and foreign-sire & foreign-dam on 1600m were less than numbers of domestic-sire & domestic-dam and foreign-sire & domestic-dam both on turf and dirt tracks. The number of foreign-sires & domestic-dams did not decrease so much. Therefore, we thought that the influence of foreign-sire and foreign-dam could not be ignored for genetic improvement in Japan.

Figures 6-3 and 6-4 show the genetic trends of four combinations by their foal's birth year at 1600m on turf and dirt tracks, respectively. On turf track (Figure 6-3), means of breeding value of foreign-sire & domestic-dam were worse than total mean in all birth year. However, the most values of other three combinations were better than total mean. Especially values of foreign-sire & foreign-dam from 1986 to 1990 were best among four combinations. And also, their values of domestic-sire & foreign-dam in 1985 and 1986 changed worse. This suggests that sire and/or dam who had unknown or low evaluations were bred in these year. On dirt track (Figure 6-4), their values of foreign-sire & foreign-dam were better than it of domestic-sire & foreign-dam and the genetic trend of foreign-sire & foreign-dam was improved more than other three combinations through all year, except for 1982, 1983 and 1986 of birth year. This suggests that evaluation of the foreign-sire influenced this trend.

It was clear that the difference of combinations of sire and dam influenced the genetic trend for racing time, although horses used in this study were registered to JRA. The trend of foreign-dam bred by foreign-sire was better than the other

Table 6-1. Change of the number of sire and dam of horse registered to JRA by their breeding area and birth year

Birth year	Sire			Dam		
	Domestic	Foreign	Sub total	Domestic	Foreign	Sub total
1975	160 (43.4)[a]	209 (56.6)	369 (100)	2,450 (83.6)	481 (16.4)	2,931 (100)
1976	183 (45.3)	221 (54.7)	404 (100)	2,552 (84.6)	465 (15.4)	3,017 (100)
1977	188 (46.0)	221 (54.0)	409 (100)	2,537 (85.5)	432 (14.5)	2,969 (100)
1978	208 (48.4)	222 (51.6)	430 (100)	2,651 (85.8)	438 (14.2)	3,089 (100)
1979	188 (46.2)	219 (53.8)	407 (100)	2,831 (87.6)	401 (12.4)	3,232 (100)
1980	187 (46.2)	218 (53.8)	405 (100)	2,975 (88.9)	372 (11.1)	3,347 (100)
1981	183 (45.4)	220 (54.6)	403 (100)	2,993 (89.5)	351 (10.5)	3,344 (100)
1982	205 (49.3)	211 (50.7)	416 (100)	3,286 (91.5)	305 (8.5)	3,591 (100)
1983	215 (51.8)	200 (48.2)	415 (100)	3,390 (93.0)	254 (7.0)	3,644 (100)
1984	217 (52.2)	199 (47.8)	416 (100)	3,486 (93.5)	244 (6.5)	3,730 (100)
1985	224 (55.6)	179 (44.4)	403 (100)	3,636 (95.0)	191 (5.0)	3,827 (100)
1986	266 (60.2)	176 (39.8)	442 (100)	3,878 (95.0)	203 (5.0)	4,081 (100)
1987	305 (63.5)	175 (36.5)	480 (100)	4,004 (95.2)	201 (4.8)	4,205 (100)
1988	332 (64.8)	180 (35.2)	512 (100)	4,068 (94.7)	229 (5.3)	4,297 (100)
1989	365 (68.2)	170 (31.8)	535 (100)	4,076 (93.6)	280 (6.4)	4,356 (100)
1990	357 (65.6)	187 (34.4)	544 (100)	4,059 (91.8)	364 (8.2)	4,423 (100)

[a] Percentage in ( )

Table 6-2. Summary of combinations of sire and dam by their birth area and their foal's birth year at 1600m on turf track

Birth year of foal	Domestic-sire & domestic-dam	Domestic-sire & foreign-dam	Foreign-sire & domestic-dam	Foreign-sire & foreign-dam	Total
1975	108 (10.1)[a]	18 (1.7)	757 (70.9)	185 (17.3)	1,068 (100)
1976	151 (13.6)	38 (3.4)	757 (68.0)	167 (15.0)	1,113 (100)
1977	119 (11.7)	24 (2.4)	719 (71.0)	151 (14.9)	1,013 (100)
1978	187 (15.7)	24 (2.0)	818 (68.6)	164 (13.7)	1,193 (100)
1979	204 (17.5)	24 (2.1)	790 (67.8)	147 (12.6)	1,165 (100)
1980	212 (17.3)	31 (2.5)	843 (68.8)	139 (11.4)	1,225 (100)
1981	219 (19.2)	18 (1.6)	786 (69.0)	116 (10.2)	1,139 (100)
1982	294 (24.7)	35 (2.9)	771 (64.8)	90 (7.6)	1,190 (100)
1983	287 (23.0)	20 (1.6)	860 (69.1)	78 (6.3)	1,245 (100)
1984	322 (25.4)	25 (2.0)	843 (66.5)	78 (6.1)	1,268 (100)
1985	388 (32.0)	17 (1.4)	758 (62.6)	48 (4.0)	1,211 (100)
1986	418 (31.5)	14 (1.1)	845 (63.7)	49 (3.7)	1,326 (100)
1987	426 (33.2)	25 (1.9)	790 (61.5)	43 (3.4)	1,284 (100)
1988	411 (33.6)	23 (1.9)	742 (60.7)	46 (3.8)	1,222 (100)
1989	483 (37.0)	22 (1.7)	741 (56.9)	57 (4.4)	1,303 (100)
1990	476 (36.6)	31 (2.4)	722 (55.4)	73 (5.6)	1,302 (100)

[a] Percentage in ( )

Table 6-3. Summary of combinations of sire and dam by their birth area and their foal's birth year at 1600m on dirt track

Birth year of foal	Domestic-sire & domestic-dam	Domestic-sire & foreign-dam	Foreign-sire & domestic-dam	Foreign-sire & foreign-dam	Total
1975	74 (10.9)[a]	12 (1.7)	486 (71.5)	108 (15.9)	680 (100)
1976	93 (14.6)	23 (3.6)	438 (68.6)	84 (13.2)	638 (100)
1977	82 (11.1)	21 (2.8)	527 (71.2)	110 (14.9)	740 (100)
1978	112 (17.3)	11 (1.7)	426 (65.7)	99 (15.3)	648 (100)
1979	111 (16.9)	18 (2.7)	436 (66.3)	93 (14.1)	658 (100)
1980	103 (16.9)	16 (2.6)	431 (70.8)	59 (9.7)	609 (100)
1981	113 (20.1)	7 (1.2)	379 (67.3)	64 (11.4)	563 (100)
1982	158 (24.9)	16 (2.5)	404 (63.6)	57 (9.0)	635 (100)
1983	131 (24.0)	15 (2.7)	366 (67.2)	33 (6.1)	545 (100)
1984	136 (27.0)	13 (2.6)	325 (64.5)	30 (5.9)	504 (100)
1985	172 (28.8)	12 (2.0)	393 (65.7)	21 (3.5)	598 (100)
1986	142 (29.3)	11 (2.3)	314 (64.7)	18 (3.7)	485 (100)
1987	132 (35.6)	11 (3.0)	212 (57.1)	16 (4.3)	371 (100)
1988	150 (36.3)	8 (1.9)	244 (59.1)	11 (2.7)	413 (100)
1989	153 (35.4)	12 (2.8)	242 (56.0)	25 (5.8)	432 (100)
1990	168 (39.0)	10 (2.3)	237 (55.0)	16 (3.7)	431 (100)

[a] Percentage in ( )

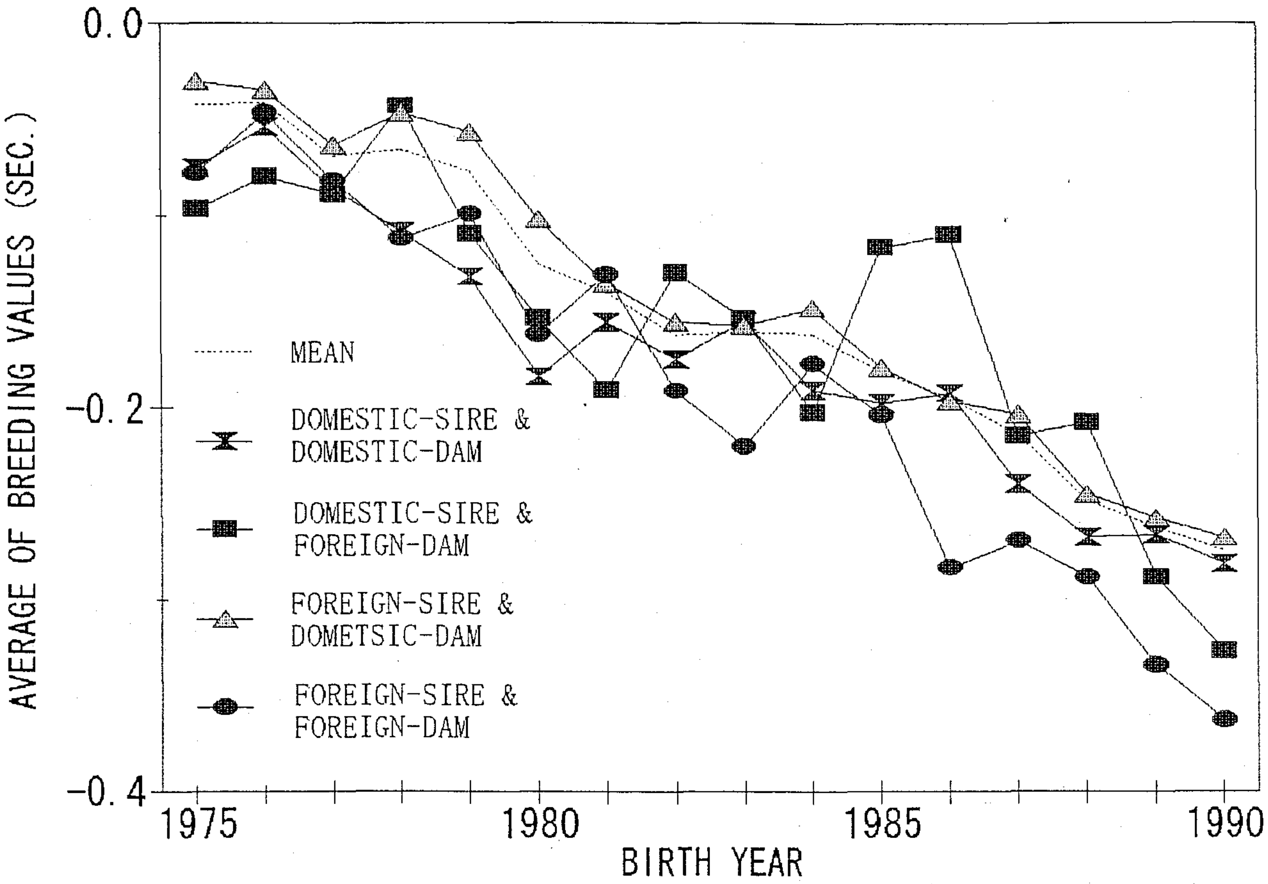

Figure 6-3. Genetic trends of their combination of sire and dam by their foal's birth year at 1600m on turf track.

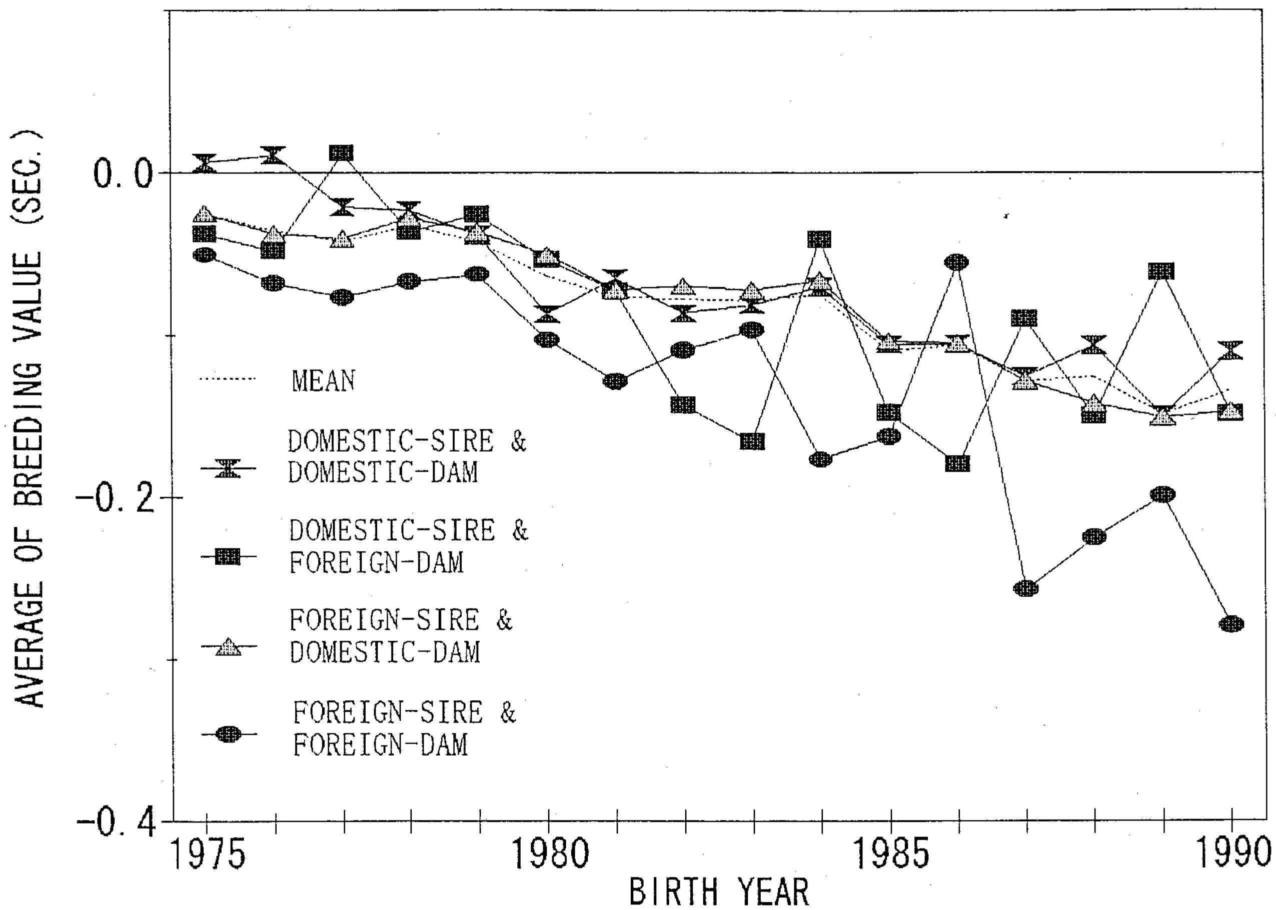

Figure 6-4. Genetic trends of their combination of sire and dam by their foal's birth year at 1600m on dirt track.

combinations both on turf and dirt tracks.

SUMMARY AND DISCUSSION

The breeding of the Thoroughbred horse started about 300 year ago in England and they have been selected by racing. The racing performance of Thoroughbred horse is evaluated usually in this field based on racing time ,earnings, earnings index, handicap weights, margins of arrivals, placing, performance rates TIMEFORM handicap ratings. In foreign countries, there are some reports by using these indicators. In Japan, however, the history of breeding for Thoroughbred horses is short. And Thoroughbred horses in Japan were believed to be beneath foreign horses in the racing performance. Since the animal breeding for the horse is later than it of a beef cattle or a milking cow, we have to establish it based on race records for the evaluation of Thoroughbred horse.

This paper reports the racing time as an indicator of racing performance and establish guides base on them to apply the best linear unbiased prediction (BLUP) method for the Thoroughbred horse in Japan.

The Japan Racing Association (JRA) operates 10 national racecourses with both turf and dirt tracks. JRA formulates the rules for horse racing; registers owners, colors, and horses using foal registration; and licenses all JRA trainers and jockeys. In 1990, at the 10 racecourses there were 288 racing days, 3,353 races, and some 38,397 horses. Horse breeding is concentrated in 7 locations with 93% of the Thoroughbreds foaled each year coming from Hokkaido. Thoroughbred flat racing comprise 92% of all races held. Two year olds race together and nearly 40% of their races are run at 1200m. Some 39% of the three year olds races are at 1800m. For 3 (and 4) year olds, the range in distances is from 1000m to 3600m. The average, over years, of the number of race records per race for 2 year olds is 10.0 and for 3 year olds and up is 11.3. The average for race records per horse for 2 year olds is 3.5 and for 3 year olds and up is 6.7. This average for horses raced per year for 2 year olds is 1,164 and 4,240 for 3 year olds and up. Horses raced per sire averaged over years was 4.6 for 2 year olds and 10.5 for the older ages. The linear regression of seconds per 100m fit the average seconds reported for the several distances run almost perfectly with R^2 values greater than .99 for all horse ages on either turf or dirt. There is selection practiced as indicated by horse numbers registered and their numbers over ages for stallions and mares. Less than .2% of the horses raced are geldings. A high degree of control exists by JRA in horse stabling and distribution of racing by horses over racecourses. Jockeys are trained by JRA, ride at several race courses, and ride for many trainers.

Data collected by the Japan Racing Association (JRA) were individual horse racing times at eight racecourses (Hakodate, Fukushima, Niigata, Tokyo, Nakayama, Chukyo, Kyoto, and Hanshin) and at five distances (1000m, 1200m, 1400m, 1600m, and 1800m) from 1982 to 1990. Important sources of variation in racing time were examined using a nested model and expressing the variance components as percentages of the total on both turf and dirt. At all racecourses and at all distances where races were on both turf and dirt, racing times were less on turf than dirt. Differences were from 2.09s to 3.91s that increased as distance increased except for 1000m and 1200m on dirt where the starting gate are at different locations. The total variance increased with distance on both turf and dirt and at each distance the total variance was larger on dirt than turf, except for 1000m, as was the residual variance. Racecourse accounted for a small fraction of the variance.

Years within racecourses were unimportant. Months within years and courses were important. Months accounted for an average of 12.7% of the total variance on turf and 8.8% on dirt indicating an effect of season that influences racing speed more on turf than dirt. Days within months, years, and courses were important and larger on turf (average was 8.6%) than dirt (average 2.4%). Races within days, months, years, and racecourses accounted for an average of 33.2% on turf and 40.2% on dirt. Clearly races accounted for the largest percentage of the total variance. Racecourse and years within course accounted for less variance than that found in American Quarter horse data, but months, days and races accounted for similar variances. Results suggest that racing speed on turf was more influenced by month and day than speed on dirt in data on Japanese Thoroughbreds. Clearly individual race is the logical contemporary group within which to make genetic predictions among horses.

Individual racing times for Japanese Thoroughbred horse at 10 racecourses from 1980 to 1990 collected by the Japan Racing Association were used. Five distance on turf and dirt were studied to ascertain the importance of sex, age, and sex by age effects and the influence of weight carried on racing times. Individual races having at least two sexes and two ages within each sex were used as incomplete blocks to study the effects. Races were important at all distances on both turf and dirt. The interaction between sex and age was unimportant. The effect of sex and/or age was significant except at 1800m and 2000m on turf. Mares were faster than stallions on turf at all distances, but on dirt stallions were faster than mares except at 1200m. In general, 5 years olds were faster than 3 and 4 year olds except at 1600m on turf. The partial regression of racing times on weight carried were significant at all distances on turf and dirt. The effects of sex and age were significant statistically and weight carried appears to be important at the distances run in Thoroughbred races.

The effects of race, age, jockey and weight carried on racing time in Japanese Thoroughbred horses were examined by the hypothesis testing ($H:K'b=0$) of the fixed effects in the mixed model. The data used were collected by Japan Racing Association from 1988 to 1990. Only races having more than two ages and the connectedness between jockeys and horses were used. The data were also analyzed with and without the inverse of the numerator relationship matrix. The significance levels did not change regardless of whether the A^{-1} was incorporated or not in the mixed model equations probably. Race, jockey and weight carried were found to have highly significant ($P<.01$) effects on racing time over six different racing distances on turf and dirt tracks. It is important to note that since the skill of the jockey is an important source of variation in racing time across distances and track types, it should be considered in deriving adjustment factors, estimating genetic parameters, and predicting genetic values for race horses.

Genetic parameter was estimated for repeated racing times on the same Thoroughbred horse by racing distance both turf and dirt by used animals' additive genetic and permanent environmental model of MTDFREML. The data used were collected by JRA from 1986 to 1990 and the effects of individual race, sex, age, jockey and weight carried were used. The generation 2 pedigree information was preferable for analysis of variance estimates. Heritability seems to decrease as the racing distance increase. These values were .25, .16, .10, .12, .09 and .08 at 1000m, 1200m, 1400m, 1600m, 1800m and 2000m, respectively, on turf, and .19, .22, .12, .09 and .17 at 100m, 1200, 1400m, 1600m and 1800m, respectively, on dirt track. The values of repeatability were from .43 to .70 on turf, and from .51 to .67 on dirt track. These suggest that racing times at the different racing distances may be regarded as different traits when the horse is to be evaluated genetically.

The breeding value of the Thoroughbred horse was predicted by the best linear unbiased prediction (BLUP) and the genetic trend for racing time were estimated. And we discussed that the evaluation of foreign-sire and foreign-dam influenced this trend. The data used were collected by JRA on the 1600m distance from 1975 to 1993. Breeding values were estimated by used animals' additive genetic and permanent environmental model of MTDFREML. The trend of breeding value became better on turf and dirt tracks as birth year. The difference of four combinations (domestic-sire & domestic-dam, domestic-sire & foreign-sire, foreign-sire & domestic-dam and foreign-sire & foreign-dam) influenced the genetic trend for racing time. The trend of foreign-dam bred by foreign-sire was better than the other combinations both on turf and dirt tracks.

This study suggests that individual race, sex, age, jockey and weight carried should be taken into account to make genetic and performance prediction on racing time in the Thoroughbred horse. Since the evaluation of sire and dam influenced the genetic trend, it is important that sire and dam are evaluated correctly. And I hope that this report contribute to the improvement of the Thoroughbred horse in Japan.

ACKNOWLEDGEMENT

We would like to thank you Prof. Y.Sasaki for your suggestion and are grateful to Dr. R.L.Willham for valuable discussion. And we Also acknowledge to Dr. C.Y.Lin for useful program and mathematical suggestion.

LITERATURE CITED

Artz,W. 1961. A contribution on the evaluation of performance tests in Thoroughbred breeding with special reference to the racing performance of individual stallion progeny groups. Gissen. Schriftenreihe Tierz. Haustiergenet. 2:1-62

Boldman,K.G. and L.D.Van Vleck. 1991. Derivative-free restricted maximum likelihood estimation in animal models with a sparse matrix solver. J. Dairy Sci. 74:4337.

Boldman,K.G., L.A.Kriese, L.D.Van Vleck and S.D.Kachman. 1993. A manual for use of MTDFREML. A set of programs to obtain estimates of variances and covariances [DRAFT]. U.S. Department of Agriculture, Agriculture Research Service.

Bormann,P. 1966. Comparison between the handicap weight and timing as measures of selection in thoroughbred breeding. Züchtungskunde 38:301-310.

Buttram, S.T., R.L.Willham and D.E.Wilson. 1988. Genetics of racing performance in the American Quarter Horse: II.Adjustment factors and contemporary groups. J. Anim. Sci. 66:2800.

Buttram,S.T., D.E.Wilson, and R.L.Willham. 1988. Genetics of racing performance in the American quarter horse: III. Estimation of variance components. J.Anim.Sci. 66:2808.

Dempfle, L. 1990. "Problems in the use of the relationship matrix in animal breeding". In Advances in Statistical Methods for Genetic Improvement of Livestock. Springer-Verlag. 454-473.

Dusek, J. 1971. Some biological factors and factors of performance in the study of heredity in horse breeding. Scientia Agriculturae Bohemoslovaca. 3:199.

Dusek, J. 1975. Analysis of racing speed achieved by thoroughbred horses. part 2: The effect of climatic and racecourse condition on speed. Bull. Vyzkumna Stanice pro Chov Koni Slatinany. 24:23.

Gillespie, R.H. 1971. A new way to evaluate race horses, performance rates. The Thoroughbred Record. 193:961.

Graser,H.U., S.P.Smith and B.Tier. 1987. A derivative-free approach for estimating variance components in animal models by restricted maximum likelihood. J.Anim.Sci. 64:1362-1370.

Henderson, C.R. 1984. Applications of Linear Models in Animal Breeding. Univ. of Guelph, Canada.

Hintz,R.L. 1980. Genetic of performance in the horse. J.Anim.Sci.51:582.

Hintz, R.L. and L.D.van Vleck. 1978. Factors influencing racing performance of the Standard pacer. J.Anim.Sci. 46:60.

Huizinga, H.A., M. Boukamp, and G. Smolders. 1990. Estimated parameters of field performance testing of mares from the Dutch Warmblood riding horse population. Livest. Prod. Sci. 26:291-299.

Huizinga,H.A., J.H.J.van der Werf, S.Korver and G.J.W.van der Meij. 1991. Stationary performance testing of stallions from the Dutch Warmblood riding horse population. 1.Estimated genetic parameters of scored traits and the genetic relation with dressage and jumping competition from offspring of breeding stallions. Livest. Prod. Sci. 27:231-244.

Japan Bloodhorse Breeders Association. 1988. Keishuba seisan tokei, part 1. 42-45. Nihon Keishuba Kyokai. Tokyo.

Katona, O. and K.Osterkorn. 1977. Genetic-statiscal analysis of racing time in the German trotter population. Zuchtungskunde. 49:185.

Katona, Ö. 1979. Genetical-statistical analysis of traits in the german trotter. Livestock Prod.Sci. 6:407.

King of Sports. 1992. A guide to horse racing in Japan. Japan Racing Association. Tokyo, Japan.

Langlois, B. 1975. Statistical and genetic analysis of eraning of 3-year-old thoroughbreds in French flat race from 1971 to 1973. Ann. Genet. Sel. Anim. 7:387.

Lejukole,H., R.Sakuma, K.Moriya, and Y.Sasaki. 1993. Restricted maximum likelihood estimation of heritabilities for growth and feed utilization traits in Japanese black using performance-test records. Anim. Sci. Technol. (Jpn.). 64:659.

Lin, C.Y., A.J.McAllister, T.R.Batra, A.J.Lee, G.L.Roy, J.A.Vesely, J.M.Wauthy and K.A.Winter. 1984. Reproductive performance of crossline and pureline dairy heifers.J.Dairy Sci. 67:2420-2428

Meyer,K. 1988a. DFREML-a set of programs to estimate variance components under an individual animal model. J. Dairy Sci. 71(Suppl. 2):33.

Meyer,K. 1988b. Programs to estimate variance components for individual animal models by restricted maximum likelihood (REML). User notes, Edinburgh Univ., Scotland.

Meyer,K. 1989. Restricted maximum likelihood to estimate variance components for animal models with several random effects using a derivative-free algorithm. Genet. Sel. Evol. 21:317.

Minkema, D. 1975. Studies on the genetics of trotting performance in Dutch trotters. Ann.Génét.Sél.anim. 7:99.

Oikawa,T., K.Sato, Y.Kawamoto, Y.Mizoguchi, H.Nakahara, and K.Hiramoto. 1994. The effect of pedigree information on variance components estimation with field carcass records of beef cattle. Anim. Sci. Technol. (Jpn.). 65:75.

Ojala, M.J. and L.D.Van Vleck. 1981. Measures of racetrack performance with regard to breeding evaluation of trotters. J.Anim.Sci. 53:611.

Ojala, M.J. 1982. Some parameters estimated from a restricted set of race records in trotters. Acta Agric.Scand. 32:215.

Ojala, M.J., L.D.Van Vleck and R.L.Quaas. 1987. Factors influencing best annual racing time in Finnish horse. J.Anim.Sci. 64:109.

Patterson H.D. and R. Thompson. 1971. Recovery of inter-block information when block sizes are unequal. Biometrika. 58:545-554.

Preisinger, R., J.Wilkens and E.Kalm. 1990. Breeding values estimation of genetic trends in German Thoroughbred horses. Proc. 4th World Congr. Appl. Livest. Prod., Edinburg. Scotland. XVI:198-201.

Racing Statistics. 1990. Japan Racing Association. Japan Racing Association. Tokyo, Japan.

Rönningen, K. 1975. Genetic and environmental factors for traits in the North-Swedish trotter. Z.Tierz.Züchtungsbiol. 92:164.

SAS. 1990. SAS® Procedure guide (Release 6.06). SAS Inst., Inc., Cary, NC, USA.

SAS. 1990. SAS/STAT® User's guide (Release 6.06). Vol.2. SAS Inst.,Inc., Cary, NC,USA.

Searle, S.R. 1971. Linear models. John Wiley & Sons. New York.

Tolley,E.A., D.R.Notter and T.J.Marlowe. 1983. Heritability and repeatability of speed for 2- and 3-year-old Standardbred racehorses. J.Anim.Sci. 56:1294.

Van der Werf,J.H.J and I.J.M. de Boer. 1990. Estimation of additive genetic variance when base populations are selected. J.Anim.Sci. 68:3124-3132.

Watanabe, Y. 1969. Timing as a measure of selection in Thoroughbred breeding. Jap.J.Zootech.Sci. 40:271.

Watanabe, Y. 1974. Performance rates of Thoroughbreds as a criterion of racing ability. Jap.J.Zootech.Sci. 45:408.

Wilson, D.E. 1990. Genetics of racing performance in the American Quarter horse: adjustments for jockey weight. Proceedings of the 4th world congress on genetics applied to livestock production, XVI. p 198.